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Importance of Acoustics in Interior Design

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***Abstract*— The main purpose of this research will focus on the differences between the three aspects of the acoustics with a special focus on the interior acoustical design. This research will clarify, strengthen, and explore the importance that has the acoustic study for the interior designing layout. From the historical eras where only material schemes were used, the acoustical treatment reached a great achievement. Nowadays, electrical, acoustical devices took place in different situations where only the materials could solve the acoustic needs. The research is focused on fundamental and importance of acoustics in Interior Design**

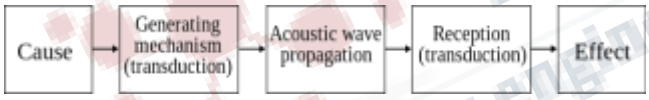
***Index Terms*— Acoustics for interiors , fundamentals of acoustics , layouts**

I. INTRODUCTION

Acoustics is the science that deals with the study of all mechanical waves in gases, liquids, and solids including vibration, sound, ultrasound and infrasound. The airborne sound inside the room i.e how it propagates and interacts with the room's surface and objects.

The application of acoustics can be seen in almost all aspects of modern society with the most obvious being the audio and noise control industries, in designing of large specialized rooms like auditoriums, conference halls, gym , cinema theaters etc.

The study of acoustics basically revolves around the generation, propagation and reception of mechanical waves and vibrations.



The central stage in the acoustical process is wave propagation. This falls within the domain of physical acoustics.

Acoustics looks first at the pressure levels and frequencies in the sound wave. Transduction processes are also of special importance.

Technically, sound is air pressure fluctuations resulting in audible vibrations. These vibrations travel in wave patterns away from the sound's source, and the waves are characterized by their frequency, wavelength, and amplitude.

When a sound-wave contacts a surface, for example a wall in a closed room, the energy and direction of the sound is altered. These alterations are perceived as sound reflections and reverberations, which can affect auditory perceptions.

1.1 FUNDAMENTALS OF ACOUSTICS:

The interior acoustical intermediate that is appropriate to the function, reaching the audience in proper level to success the communication, without disturbing or even harming the users hearing, is a prosperous acoustical design. The classification of the interior spaces could lead to a better understanding of the role of the acoustical design to succeed in the functionality of the space. The interior acoustical design differs from the spaces where speech intelligibility is necessary to the spaces where quietness is vital, to spaces where the music needs enhancements, to spaces of private.

The various important definitions related to acoustics are as follows:

- Pitch and Frequency
- Wave length
- Amplitude
- Reverberation time

1.2 FACTORS AFFECTING INTERIOR ACOUSTICAL DESIGN:

- Volume.
- Shape.
- Sound absorption.
- Site selection.
- Material selection

1.3 SPACES FOR SPEECH INTELLIGIBILITY:

As Speech clearness is vital in a specific type of functions. Without speech intelligibility, classes success could fail. Teacher explanations, court sessions, and board meetings are functional, practical examples where speech is the key role of their success. Large institutions need clear discussions to make efficient decisions.

In the court, when the speech is not clear, many judicial problems could take part from innocently. Such spaces need clear speech with no reflection nor echoes. In such

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functions, the number of absorber materials should increase in favor of the reflectors. The absorption material scheme when exceed, will produce a harmful background and thus, will require more effort from the sources to enable the audience to hear.

1.4 SPACES FOR MUSIC ENHANCEMENTS :

Recording studios, musical halls, and theaters are the locations of musical enhancement functions. Each of these areas needs different acoustical treatments to reach a vital level of sound. Studios need absorption layout to remove any reflection possible.

While the musical halls, where live music takes place, requisite a mixture between the reflection and diffusing materials to reach the life feeling of sound without echoes nor masking of sound.

1.5 SPACES FOR PRIVACY NEEDS :

Private discussion occurs in human resources offices, in a medical clinic, in residential spaces, and police stations. These environments need high absorption quality to promote the privacy necessary. One of the human feelings is to feel shame from exposing private issues.

Respecting and protecting these feelings are mandatory in designing such spaces. These kind of spaces could exist in buildings where other acoustical requirements are much necessary to take care. For Example- Doctor Room that needs privacy, during the clinic, and called for the quiet environment.

1.6 SPACES FOR PUBLIC ANNOUNCEMENTS :

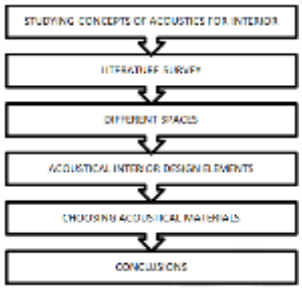
Airports, Public malls, and Governmental spaces for individual services are all spaces where public announcement occurs.

The announcement of the flight number and timing requires a clearness in the speech to understand the announced information.

Otherwise, the disruption and the distraction are the results. Acoustic design plays a different role in creating a masking background to clear the pronounced data.

II. METHODOLOGY:

2.1 METHODOLOGY CHART:



2.2 ACOUSTICAL INTERIOR DESIGN ELEMENTS :

Interior acoustics support the well-being of the users. The design of the spaces that require a sound quality needs specific elements to embolden the acoustical quality.

The interior acoustical elements involve and interlace with other acoustical fields.

These elements start by the space layout, which should be architecturally created to the specific function to prevent any basic problems.

Otherwise, the interior solutions could cover such deficiency. The selective materials are the essence of the interior acoustical design.

The interior treatments, quality, and position play the main role in the excellence of the acoustical functionality.

2.3 INTERIOR ACOUSTICAL LAYOUT:

The architectural design affects deeply in the interior sound behavior. While the sound behavior follows the architectural layout, the architectural shape could lead to a successful acoustic or a harmful one.

The architecture should support the acoustical design to enhance the functionality rather than create problems that need extra solutions.

Domes, circular plan, parallel surfaces, and unproportioned spaces lead to several acoustical problems for the interior spaces. Solving these problems will over cost the interior, as the acoustical treatments are expensive as raw materials and as fire-resistant coatings.

1. Domes:
   - Dome does reflect the sound to a specific point, creating a nonstop echo.
   - Adding absorbers on the full surfaces of the dome will create a convenient sound layout for space. Suspending of a huge luminaire, designed for masking the echo, is a solution of cutting out the reflection but in condition to use an amount of absorbing materials within its design.
   - Baffles are a different solution but, similar to the suspended luminaire, it will block the view of the dome and will create an additional different perception.

2. Circular plan:
   - Circular plan is a challenge for the acoustical design perfection.
   - Similar to some extent to the dome, straight surfaces of paneling would break the echo resulting from the circular perimeter.
   - A mixture of balanced acoustical materiality scheme is the best solution, and the decision of the properties of the materials relates to the functional acoustical study of the specific interior.

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3. Parallel surfaces:

- The interior surfaces should not have parallel surfaces, either as peripheral surfaces or as ceiling and flooring opposite to each other.
- The interior acoustical designer needs to break these parallelisms.
- The creation of acoustical interior treatments, diverse in quantities and properties, will solve this problem, although it is much expensive than having the spaces without such problems.

III. TREATMENTS

3.1 INTERIOR ACOUSTICAL TREATMENTS:

The sound behavior in the interior spaces is the result of the interior treatments used.

The quality and the properties of the materials share to some extent the success of the sound propagation within the space. The sound could be reflected, absorbed, diffused, or transmitted depending on the material physics.

Materials used in the acoustical design are expensive as their majority are natural materials. Additionally, they need exclusive fire-resistant coating.

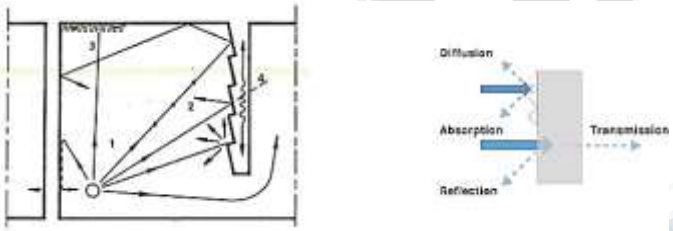

Fig. 1. Sound behavior in the enclosed spaces ((1) sound wave projected from the source, (2) sound wave reflected on the surface, (3) sound wave absorbed, and (4) sound wave transmitted).

3.1.1 REFLECTORS:

Reflectors are hard solid materials that reflect the sound following the rule of reflection—angle of projection equals to angle of reflection but in the opposite side. Oak, beech, mahogany, maple, walnut, and pine are all good selection. Ash wood is one of the best as it can easily bend which allows better coverage in favor of materiality limitations.

Convex surfaces will scatter the sound waves allowing natural reinforcement for the unamplified voice without electrical sound systems while reducing the material surfaces.

Fig. 2 Reflectors appearance in the interiors

3.1.2 ABSORBERS:

Opposite to the reflectors, absorbers are soft, porous materials. Used to name the foams with different densities and thicknesses, a sandwich panel composed from a finished layer of fabric or soft natural perforated or slotted wood (with different perforation percentages), and the inside might be one or more of the following materials: rock wool, glass wool, or foam, based on its absorption coefficient "alpha".

Heavy curtains exceed its dimensions seven times the length to work as absorbers.

Fig. 3 Perforated and slotted softwood, sandwich panels.

3.1.3 DIFFUSERS:

Diffusers are the type of treatments that deploy the sound wave in a way to keep it alive without reflecting it to a specific spot nor to absorb it.

They are hard solid materials full of angles and curves to diffuse the sound waves within the interior spaces.

Fig. 3. Diffusers in different appearances of curves and angles, through the hard solid selection

3.1.4 ISOLATION MATERIALS :

The isolation materials usually are used to prevent the transmission of the sound waves from space to another.

Spaces could be enclosed or open, but the essential is to block their flows and thus avoid the noise transmissions. However, they are part of the structure of the building layout, yet the acoustical interior may interface to solve specific noise transmission and therefore be part of the design.

Building materials are the rescue to solve such situation

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in the interior acoustical design phases.

3.1.5 INTERIOR ACOUSTICAL SOUND SYSTEM:

Electrical sound systems for the acoustical interior design are not useful, especially when the interior wall is acoustically designed.

It has dedicated purposes when recording constituents play a role in the functional aspects.

It is worth to mention that this section is an acoustical engineering field that serves the interior and its inhabitants directly.

For the acoustical interior designer, the sound system exposure to three main questionings, the what, the why, and the how of the electrical sound system

Fig.4. Sound system components (microphone, loudspeakers, and control panel)

3.2 SOUND SYSTEMS REGULATIONS:

The sound system should follow strict regulations to ensure the quality level of the sound projected.

Therefore, the strict regulations once applied, will provide the best sound system results.

The selection of sound system properties contributes to the overall design of these sound systems in the interior layout. The angles of the sound projections from the loudspeakers determine the numbers of speakers and their positions in the interiors.

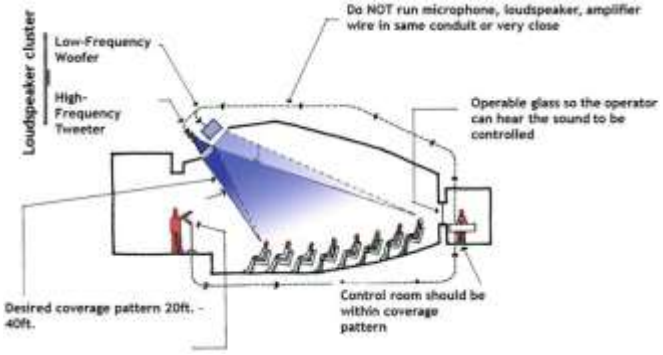

Fig.5. Sound system regulations in a section layout.

3.3 INTERIOR ACOUSTICAL DESIGN CRITERION:

Interior acoustical design is a field where mixes of discipline contribute to the sound excellence for the benefits of the users. Interior acoustical design involves the basics of physics as science relates the reflection, absorption data, the sound formula regarding the reverberation time, the physical measurements of the materials based on the coefficient of absorption (alpha ᾱ), the space volume, and the sound frequencies.

All these inputs enabled the creation of the new interior acoustical wheel -

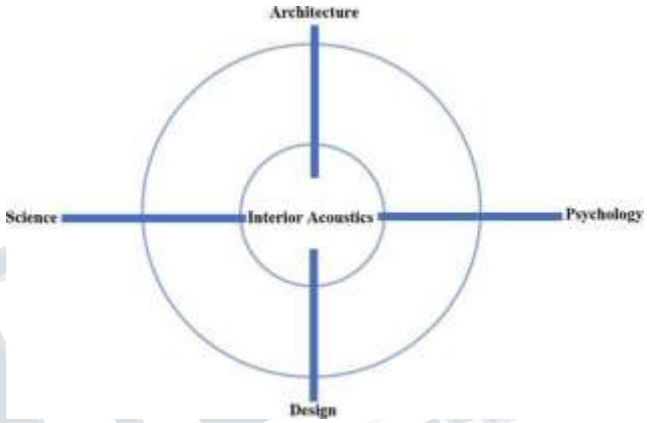

Fig.6. Interior acoustical design wheel.

Interior acoustical design implicates in parallel the artistic perception of the material selection, the material patterning, and the material color schemes. Therefore, the interior acoustical design is deliberated, as science and art, through the following points:

- ✓ The classification of functional interior permits the selection of the design paths regarding materiality schemes that support the interior function in favor of the users. The five different space functionality classifications are speech intelligibility, quiet interior, music enhancements, privacy needs, and public announcements.
- ✓ The soundscape plays a major role in the psychology scheme of the space as much it affects the users in unconscious ways.
- ✓ The interior acoustical space needs hard efforts to prevent the weakness of the architectural layout from the architectural perceptions, the domes, the parallel surfaces, the unproportioned spaces, and the circular plan's to reach an appropriate acoustical interior design.
- ✓ The interior acoustical design—or room acoustics—depends on the quality of the material properties and their positions in the interior.
- ✓ The interior acoustical material classifications are reflectors, absorbers, and diffusers.

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- ✓ Reflectors are hard solid materials, where the designer can use simple formulas to determine their position ,where “A” is the projected ray of sound, “B” is the reflected ray of the sound, and “C” is the direct ray of the sound.
- ✓ Absorbers are soft porous materials, where the coefficient of absorption alpha ($\bar{\alpha}$) specifies their level of absorption. The material is absorber if $\bar{\alpha}$ = 0.6–1. Absorbers are composite materials (sandwich panels).
- ✓ Diffusers are hard solid materials full of curves or hard edges (angles).
- ✓ Isolation materials are within the architect responsibility, yet the interior designer could refer to them when needed.
- ✓ The sound system is designed by the electrical engineers, yet it is part of the acoustical interior layout upon strict guideline of uses. The three functional parameters of the electrical sound systems are recording the events, listening to recorded materials, and simultaneous translation. The sound system should follow the rigor layout for the benefits of the output sounds.
- ✓ The sound level (measured in decibel—“dB”) appropriate to the function is standard, and the interior acoustical designer needs to follow the mathematical steps (using Sabine or Earring Formulas) to reach the convenient reverberation time (RT). These steps and formulas are part of the mechanical engineering field.
- ✓ The interior acoustical design is a combination of science, architecture, psychology, and design that contribute in interlacing paths to reach the sound excellence for the wellness of the human being.

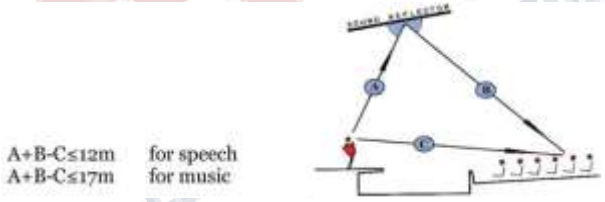

Fig.6. Reflection position formulas.

Material	Frequency (Hz)*					
	125	250	500	1.000	2.000	4.000
Acoustic Panels	0.15	0.3	0.75	0.85	0.75	0.4
Brick	0.024	0.024	0.03	0.04	0.05	0.07
Carpet	0.05	0.1	0.2	0.25	0.3	0.35
Curtains	0.05	0.12	0.15	0.27	0.37	0.5
4" Rockwool	0.38	0.89	0.96	0.98	0.81	0.87
Wood Floor (Joists)	0.15	0.2	0.1	0.1	0.1	0.05
Glass	0.03	0.03	0.03	0.03	0.02	0.02
Seated Person	0.18	0.4	0.46	0.46	0.5	0.46
Plasterboard	0.3	0.3	0.1	0.1	0.04	0.02
Plywood on 2" Batten	0.35	0.25	0.2	0.15	0.05	0.05
½" Wood Panel	0.1	0.11	0.1	0.08	0.08	0.11

*Note: A (α) coefficient of 1.0 means 100% Absorption, such as an open window, while 0.0 means 100% Reflection, such as glass. All figures are given for one square meter of materials.

Fig.7. Alpha chart to standard frequencies.

Fig.8. Sound level chart to the normal daily life, where the hearing damages are indicated

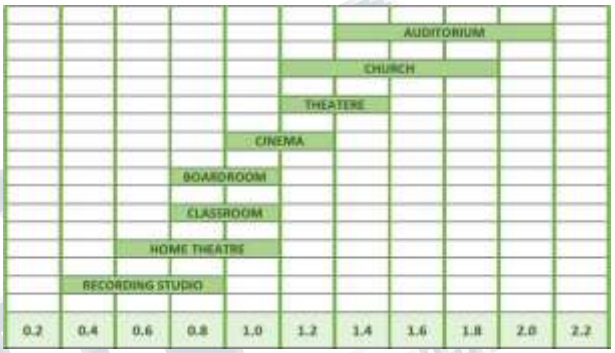

Fig.9 Reverberation time (RT) measured in seconds for specific functions.

3.4 EFFECTIVE SOLUTIONS AND MATERIALS :

For example : The acoustics of classroom will need following general modifications:

- External Modifications
- Modification of Ceilings
- Modification of Floors
- Modification of Windows
- Modification of Seating and Furniture Arrangement
- Modification of Doors
- Modification of Walls

The following absorbent materials are used in the room to make the room acoustically good:

- Hair felt.
- Acoustic Plaster
- Acoustical tiles.
- Strawboards.
- Pulp boards.
- Compressed fiber board.
- Compressed wood particle board.
- Perforated plywood.

The above mentioned solutions are very efficient in making the room acoustically good.

IV. CONCLUSION:

- ✓ Acoustics dates from the prehistorically eras, where the human considered it a vital component of the daily life, to sustain the communication.
- ✓ The uses of the architectural layout and the interior components were the tools to apply a good acoustical environment, using the science, within the historical periods.
- ✓ Interior acoustic design needs a clear classification of functional necessities to reach a successful synthesis that suits the end users of the spaces.
- ✓ The interior acoustical success relies on the quality and the locus of the materials used within the space upon stricken regulations.
- ✓ The material quality determines either it is a reflector, absorber, or diffuser.
- ✓ Reflectors are hard, rigid, and thick materials.
- ✓ Absorbers are soft and porous, and, usually, they are in the form of "sandwich panels."
- ✓ Diffusers are similar to the reflectors but never in plane surfaces, only if full of curves or angles.
- ✓ The coefficient of absorption (alpha ᾱ) factor permits to apportion the material scheme within the interior. Alpha differs upon the level frequencies. When overall alpha magnitude reaches the round of "1," it means the material is absorber, and when reaching the round of "zero," it means the material is reflector.
- ✓ Sound systems are used for only archetypical purposes and should follow the confine regulations.
- ✓ Sounds cape is an element to consider effectively, as it affects the human psychological within the interior layout.

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